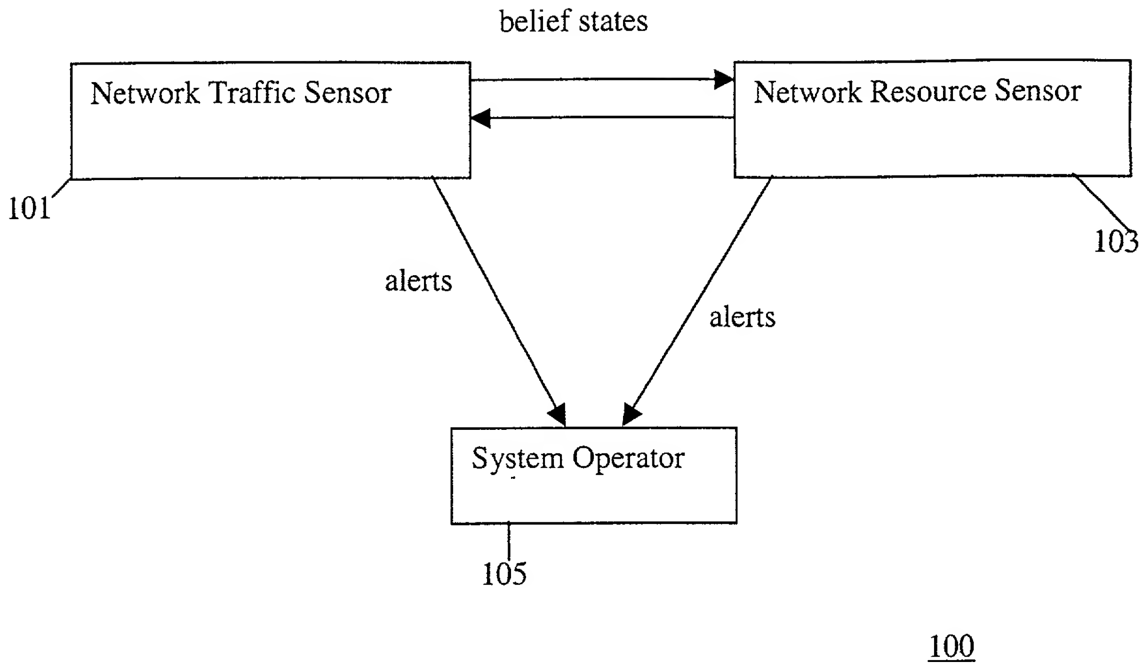

belief states
Network Traffic Sensor
Network Resource Sensor
101
103
alerts
alerts
System Operator
105
100

FIGURE 1

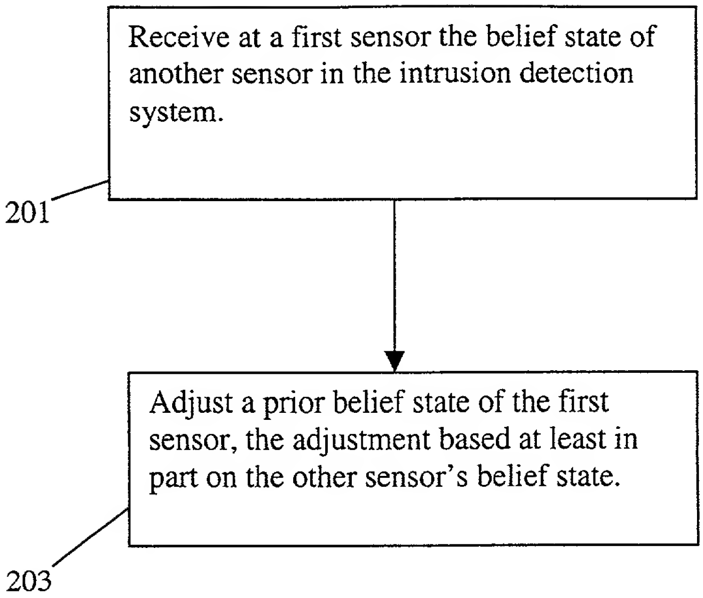

Receive at a first sensor the belief state of another sensor in the intrusion detection system.
201
Adjust a prior belief state of the first sensor, the adjustment based at least in part on the other sensor's belief state.
203

FIGURE 2

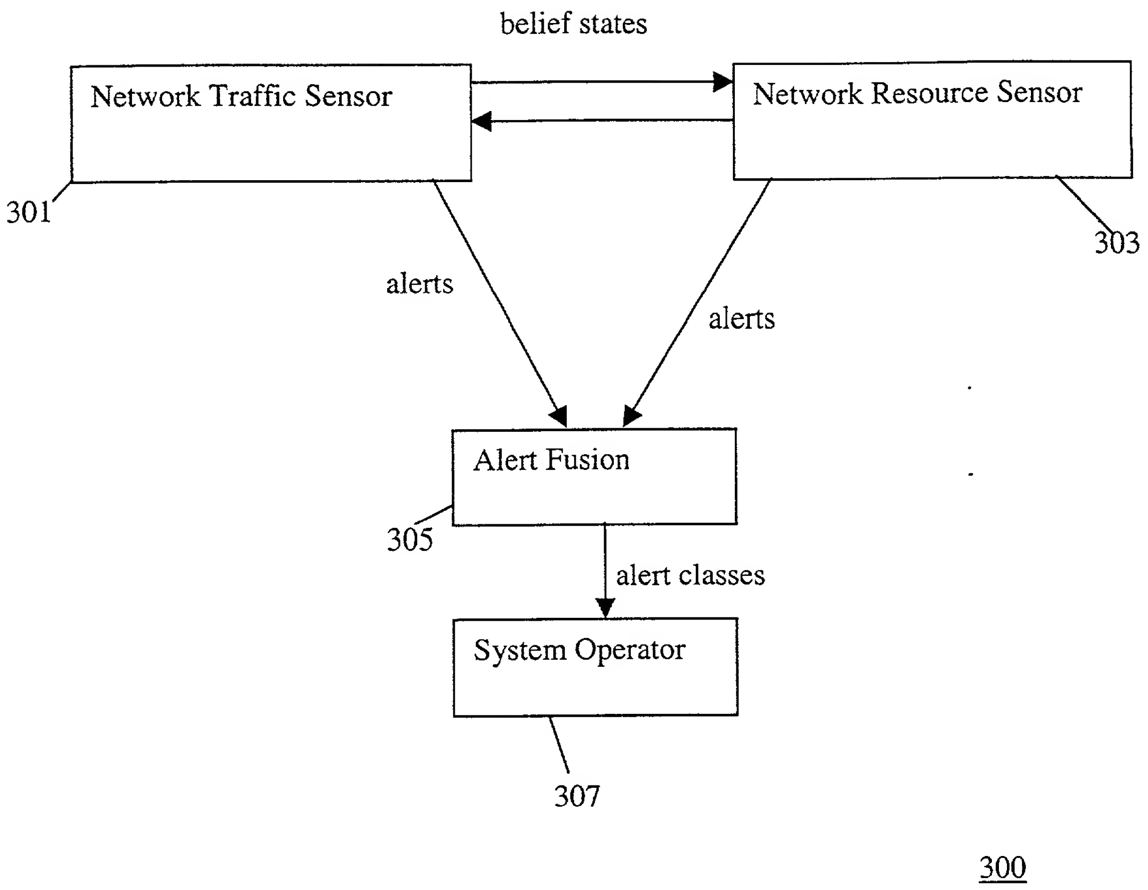

belief states
Network Traffic Sensor
Network Resource Sensor
301
303
alerts
alerts
Alert Fusion
305
alert classes
System Operator
307
300

FIGURE 3

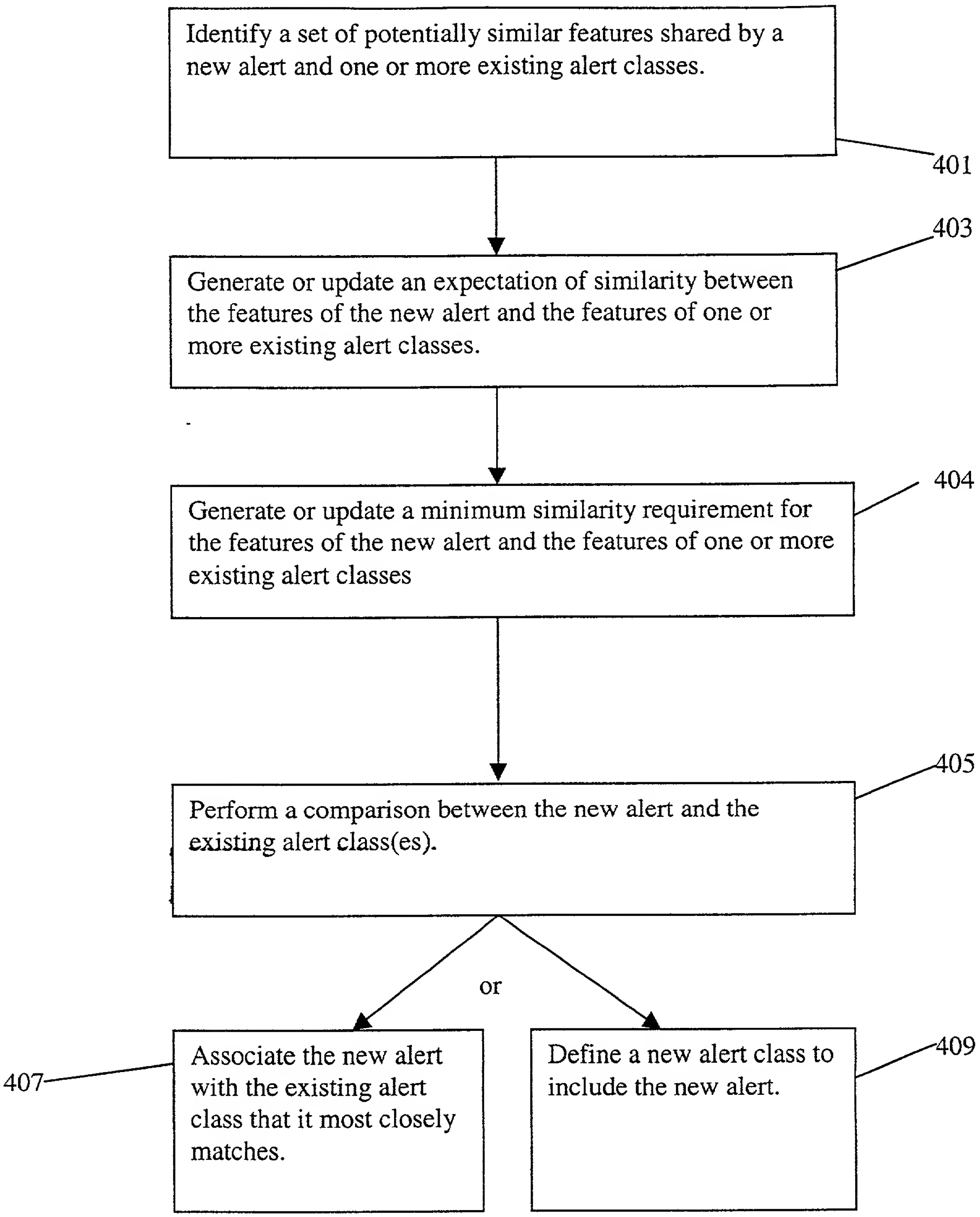
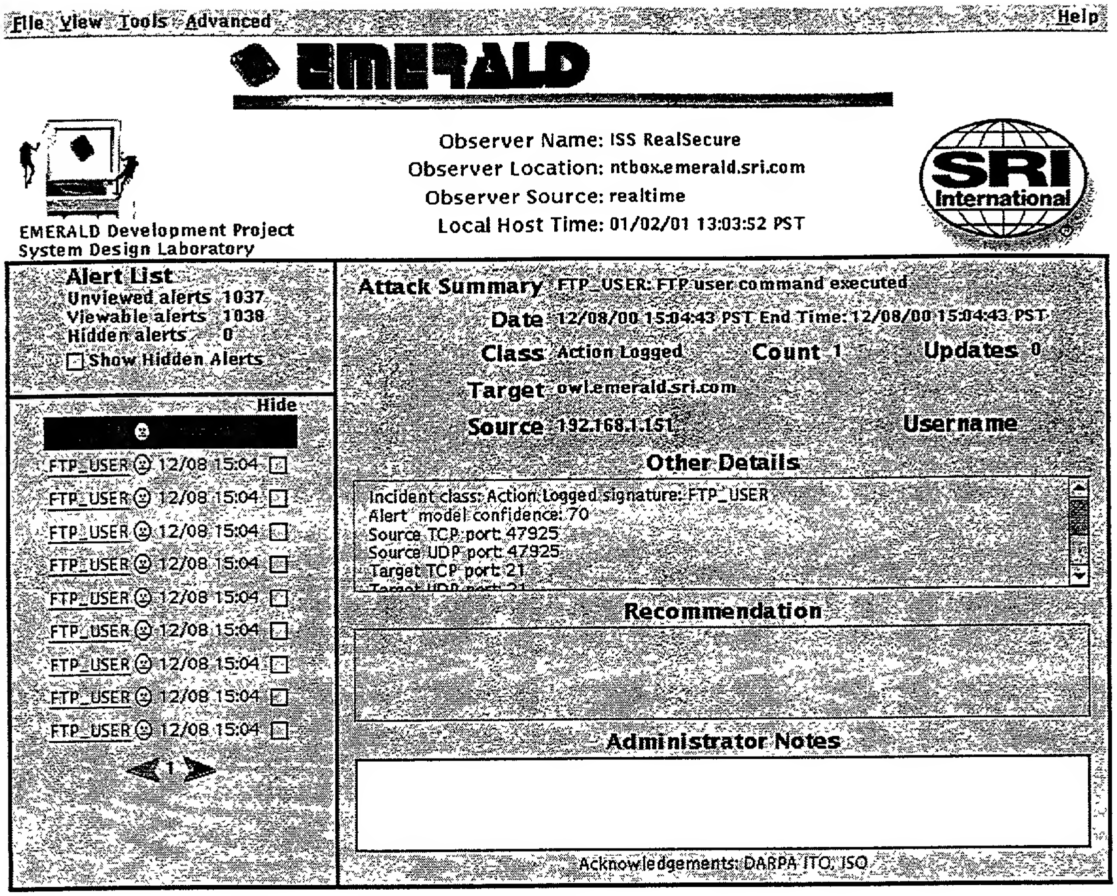

Identify a set of potentially similar features shared by a new alert and one or more existing alert classes.
401
403
Generate or update an expectation of similarity between the features of the new alert and the features of one or more existing alert classes.
404
Generate or update a minimum similarity requirement for the features of the new alert and the features of one or more existing alert classes
405
Perform a comparison between the new alert and the existing alert class(es).
or
407
Associate the new alert with the existing alert class that it most closely matches.
Define a new alert class to include the new alert.
409

FIGURE 4

	INVALID	PRIVILEGE_VIOLATION	USER_SUBVERSION	DENIAL_OF_SERVICE	PROBE	ACCESS_VIOLATION	INTEGRITY_VIOLATION	SYSTEM_ENV_CORRUPTION	USER_ENV_CORRUPTION	ASSET_DISTRESS	SUSPICIOUS_USAGE	CONNECTION_VIOLATION	BINARY_SUBVERSION	ACTION_LOGGED
INVALID	1	0.3	0.3	0.3	0 3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6
PRIVILEGE_VIOLATION	0.3	1	0.6	0.3	0 6	0.6	0.6	0.6	0.4	0.3	0.4	0.1	0.5	0.6
USER_SUBVERSION	0.3	0.6	1	0.3	0 6	0.5	0.5	0.4	0.6	0.3	0.4	0.1	0.5	0.6
DENIAL_OF_SERVICE	0.3	0.3	0.3	1	0.6	0.3	0.3	0.4	0.3	0.5	0.4	0.1	0.5	0.6
PROBE	0.3	0.2	0.2	0 3	1	0.7	0.3	0.3	0.3	0.3	0.4	0.8	0.3	0.6
ACCESS_VIOLATION	0.3	0.6	0.3	0.5	0.6	1	0.6	0.6	0.3	0.3	0.4	0.1	0.5	0.6
INTEGRITY VIOLATION	0.3	0.5	0.3	0.5	0.6	0.8	1	0.6	0.5	0.3	0.4	0.1	0.5	0.6
SYSTEM_ENV_CORRUPTION	0.3	0.5	0.3	0.5	0.6	0.6	0.6	1	0.6	0.3	0.4	0.1	0.5	0.6
USER_ENV_CORRUPTION	0.3	0.5	0.5	0.3	0.6	0.6	0.6	0.6	1	0.3	0.4	0.1	0.5	0.6
ASSET_DISTRESS	0.3	0.3	0.3	0.6	0.3	0.3	0.3	0.3	0.3	1	0.4	0.4	0.3	0.6
SUSPICIOUS_USAGE	0.3	0.3	0.5	0.3	0.5	0.6	0.5	0 6	0.5	0.3	1	0.1	0.3	0.6
CONNECTION_VIOLATION	0.3	0.1	0 1	0.3	0.8	0.3	0.3	0.3	0.3	0.5	0.4	1	0.3	0.6
BINARY_SUBVERSION	0.3	0.3	0.3	0.3	0.3	0.6	0.6	0.6	0.5	0.3	0.4	0.1	1	0.6
ACTION_LOGGED	0.3	0.3	0.3	0.3	0.6	0.5	0.3	0.3	0.3	0.3	0.4	0.3	0.3	1

Figure 5



EMERALD Development Project
System Design Laboratory

Observer Name: ISS RealSecure
Observer Location: ntbox.emerald.sri.com
Observer Source: realtime
Local Host Time: 01/02/01 13:03:52 PST

Alert List
Unviewed alerts 1037
Viewable alerts 1038
Hidden alerts 0
□ Show Hidden Alerts

FTP_USER 12/08 15:04 □
FTP_USER 12/08 15:04 □
FTP_USER 12/08 15:04 □
FTP_USER 12/08 15:04 □
FTP_USER 12/08 15:04 □
FTP_USER 12/08 15:04 □
FTP_USER 12/08 15:04 □
FTP_USER 12/08 15:04 □
FTP_USER 12/08 15:04 □

◀ 1 ▶

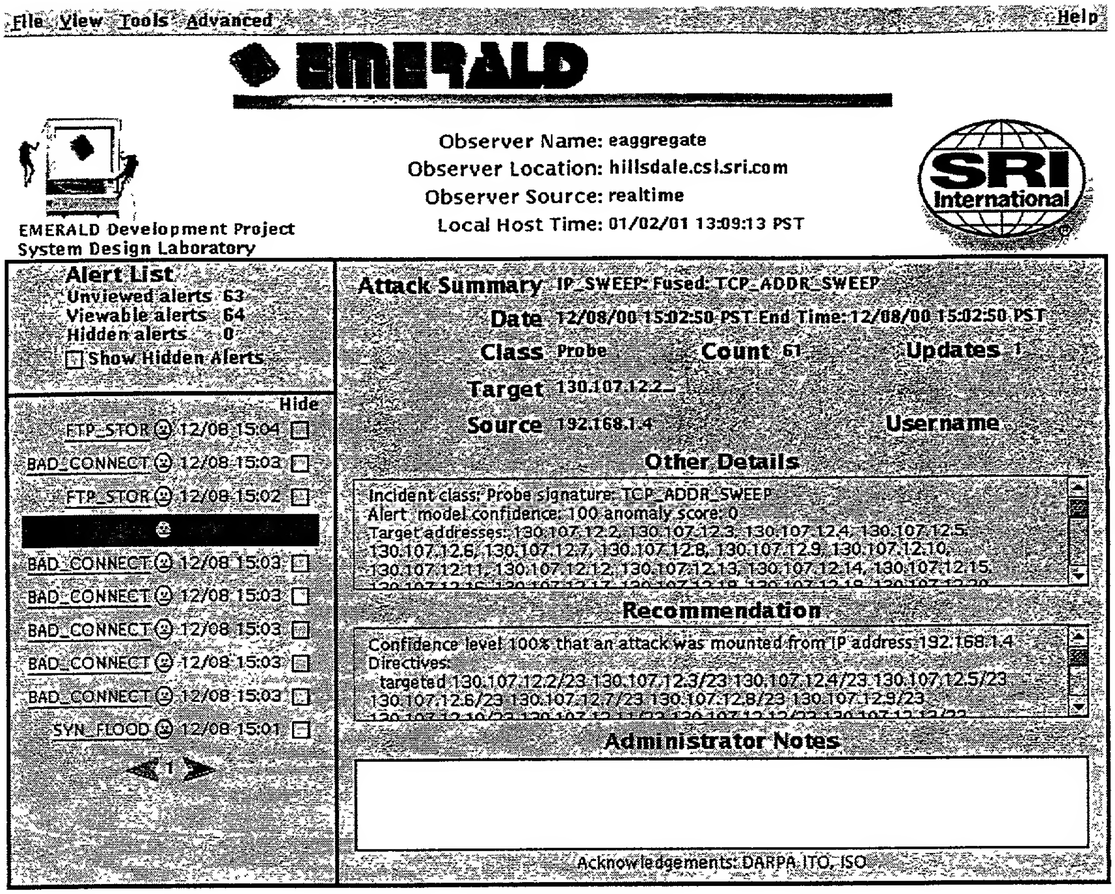
Attack Summary FTP_USER: FTP user command executed
Date 12/08/00 15:04:43 PST End Time: 12/08/00 15:04:43 PST
Class Action Logged Count 1 Updates 0
Target owl.emerald.sri.com
Source 192.168.1.151 Username

Other Details

```
Incident class: Action Logged signature: FTP_USER
Alert model confidence: 70
Source TCP port: 47925
Source UDP port: 47925
Target TCP port: 21
```

Acknowledgements: DARPA ITO, ISO

Figure 6



Observer Name: eaggregate
Observer Location: hillsdale.csl.sri.com
Observer Source: realtime
Local Host Time: 01/02/01 13:09:13 PST

EMERALD Development Project
System Design Laboratory

Alert List
Unviewed alerts 63
Viewable alerts 64
Hidden alerts 0
□ Show Hidden Alerts

Hide
FTP_STOR 12/08 15:04 □
BAD_CONNECT 12/08 15:03 □
FTP_STOR 12/08 15:02 □
BAD_CONNECT 12/08 15:03 □
BAD_CONNECT 12/08 15:03 □
BAD_CONNECT 12/08 15:03 □
BAD_CONNECT 12/08 15:03 □
BAD_CONNECT 12/08 15:03 □
SYN_FLOOD 12/08 15:01 □
< 1 >

Attack Summary IP_SWEEP: Fused: TCP_ADDR_SWEEP
Date 12/08/00 15:02:50 PST End Time: 12/08/00 15:02:50 PST
Class Probe Count 61 Updates 1
Target 130.107.12.2...
Source 192.168.1.4 Username

Other Details

Incident class: Probe signature: TCP_ADDR_SWEEP
Alert model confidence: 100 anomaly score: 0
Target addresses: 130.107.12.2, 130.107.12.3, 130.107.12.4, 130.107.12.5, 130.107.12.6, 130.107.12.7, 130.107.12.8, 130.107.12.9, 130.107.12.10, 130.107.12.11, 130.107.12.12, 130.107.12.13, 130.107.12.14, 130.107.12.15,

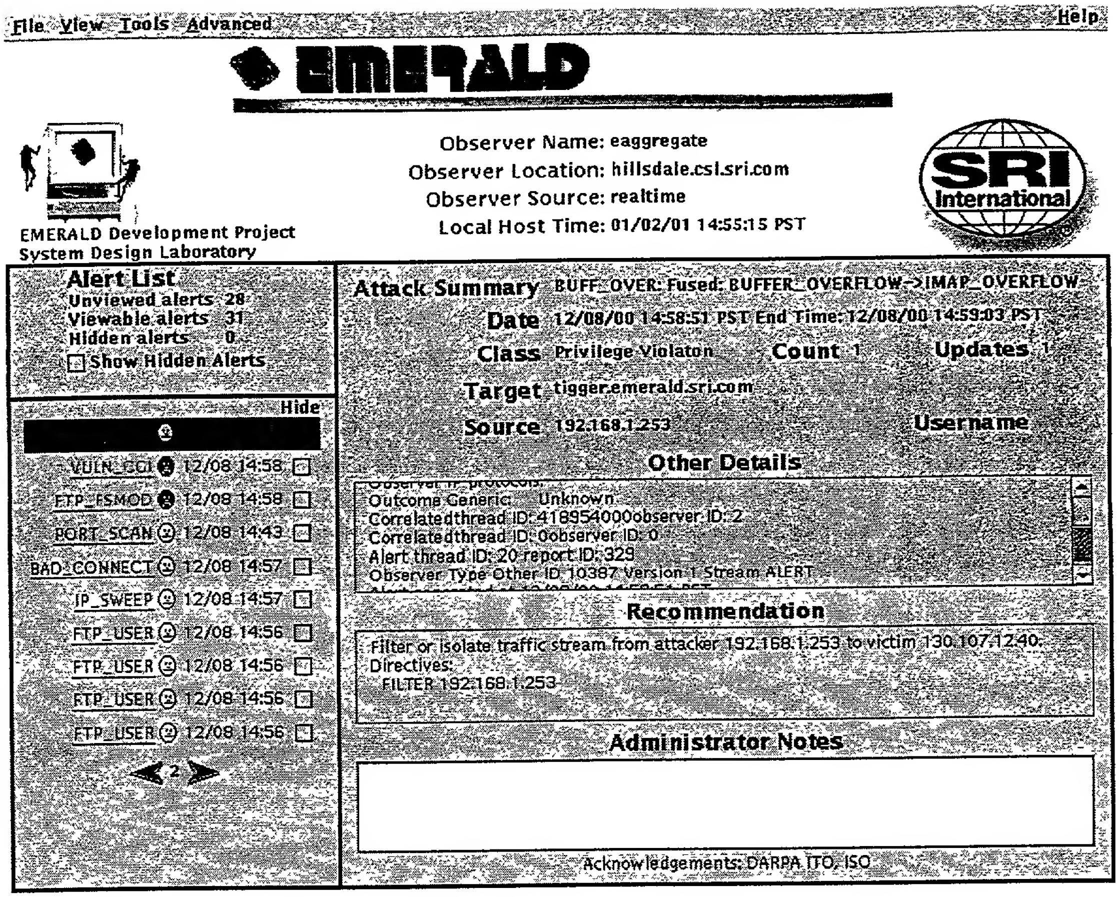
Recommendation

Confidence level 100% that an attack was mounted from IP address 192.168.1.4
Directives:
targeted 130.107.12.2/23 130.107.12.3/23 130.107.12.4/23 130.107.12.5/23 130.107.12.6/23 130.107.12.7/23 130.107.12.8/23 130.107.12.9/23

Administrator Notes

Acknowledgements: DARPA ITO, ISO

Figure 7



EMERALD Development Project
System Design Laboratory

Observer Name: eaggregate
Observer Location: hillsdale.csl.sri.com
Observer Source: realtime
Local Host Time: 01/02/01 14:55:15 PST

Alert List
Unviewed alerts 28
Viewable alerts 31
Hidden alerts 0
□ Show Hidden Alerts

		Hide
VULN_CGI ●	12/08 14:58	□
FTP_FSMOD ●	12/08 14:58	□
PORT_SCAN ○	12/08 14:43	□
BAD_CONNECT ○	12/08 14:57	□
IP_SWEEP ○	12/08 14:57	□
FTP_USER ○	12/08 14:56	□
FTP_USER ○	12/08 14:56	□
FTP_USER ○	12/08 14:56	□
FTP_USER ○	12/08 14:56	□

Attack Summary BUFF_OVER: Fused: BUFFER_OVERFLOW->IMAP_OVERFLOW
Date 12/08/00 14:58:51 PST End Time: 12/08/00 14:59:03 PST
Class Privilege Violaton **Count** 1 **Updates** 1
Target tigger.emerald.sri.com
Source 192.168.1.253 **Username**

Other Details

```
Outcome Generic:    Unknown
Correlatedthread ID: 418954000observer ID: 2
Correlatedthread ID: 0observer ID: 0
Alert thread ID: 20 report ID: 329
Observer Type Other ID 10387 Version 1 Stream ALERT
```

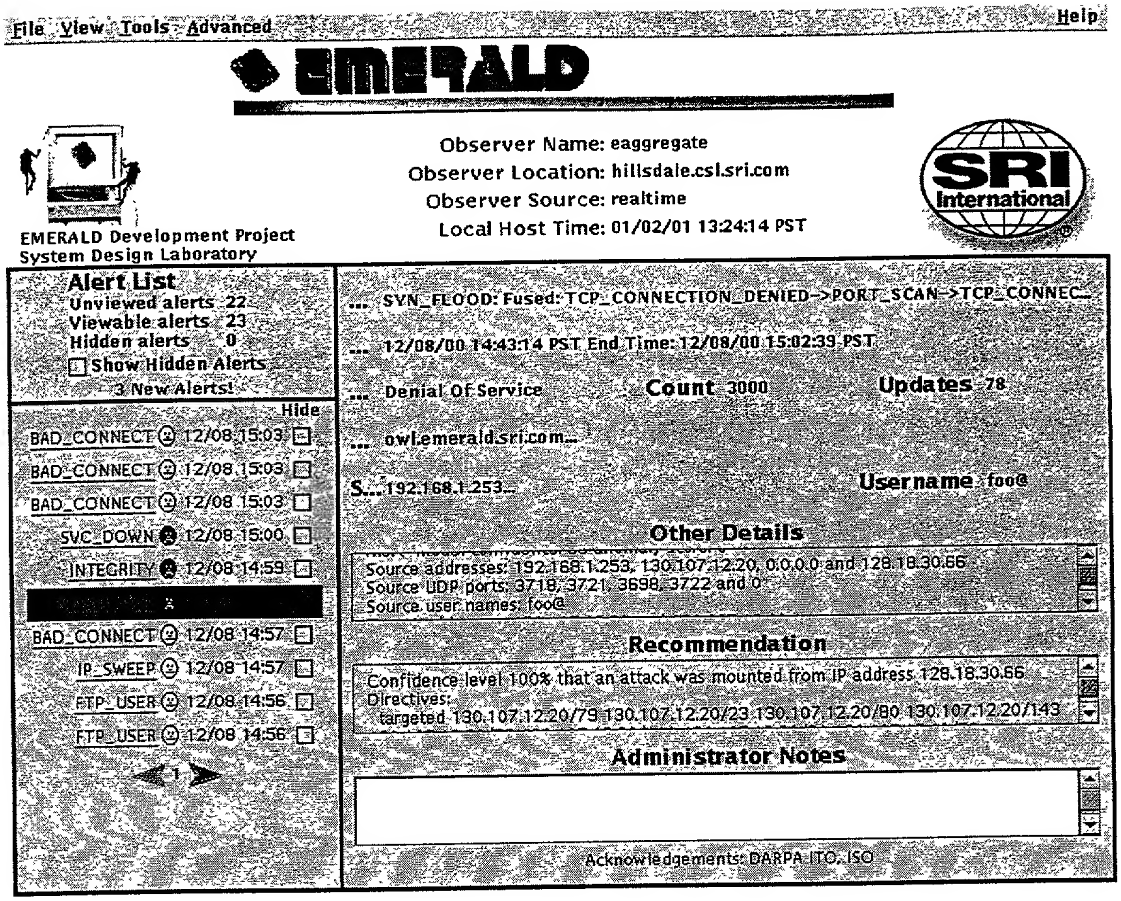
Recommendation

Filter or isolate traffic stream from attacker 192.168.1.253 to victim 130.107.12.40.
Directives:
FILTER 192.168.1.253

Administrator Notes

Acknowledgements: DARPA ITO, ISO

Figure 8



Observer Name: eaggregate
Observer Location: hillsdale.csl.sri.com
Observer Source: realtime
Local Host Time: 01/02/01 13:24:14 PST

EMERALD Development Project
System Design Laboratory

Alert List
Unviewed alerts 22
Viewable alerts 23
Hidden alerts 0
□ Show Hidden Alerts
3 New Alerts!

Hide
BAD_CONNECT 12/08 15:03 □
BAD_CONNECT 12/08 15:03 □
BAD_CONNECT 12/08 15:03 □
SVC_DOWN 12/08 15:00 □
INTEGRITY 12/08 14:59 □
BAD_CONNECT 12/08 14:57 □
IP_SWEEP 12/08 14:57 □
FTP_USER 12/08 14:56 □
FTP_USER 12/08 14:56 □
1

... SYN_FLOOD: Fused: TCP_CONNECTION_DENIED->PORT_SCAN->TCP_CONNEC...
... 12/08/00 14:43:14 PST End Time: 12/08/00 15:02:39 PST
... Denial Of Service Count 3000 Updates 78
... owl.emerald.sri.com...
S... 192.168.1.253... Username foo@

Other Details

Source addresses: 192.168.1.253, 130.107.12.20, 0.0.0.0 and 128.18.30.66
Source UDP ports: 3718, 3721, 3698, 3722 and 0
Source user names: foo@

Recommendation

Confidence level 100% that an attack was mounted from IP address 128.18.30.66
Directives:
targeted 130.107.12.20/79 130.107.12.20/23 130.107.12.20/80 130.107.12.20/143

Administrator Notes

Acknowledgements: DARPA ITO, ISO

Figure 9